N69-78378

9. THE CURRENT USWB METEOROLOGICAL SATELLITE PROGRAM

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A rather comprehensive review of the TIROS meteorological satellite program upon which most of the research activities in the Weather Bureau are based has been given in paper 8.

The research activities in the meteorological satellite program in the Weather Bureau are centralized in the Meteorological Satellite Laboratory. The Laboratory is primarily concerned with meteorological research utilizing satellite observations in order to increase the understanding of the atmosphere and, at the same time, to develop new and improved techniques for analysis and forecasting.

Because of concern with the nature of the observations, the Laboratory also participates in the satellite experiment design and in basic instrument development. The volume of meteorological data obtained by the satellite averages millions of bits of data per day. This causes serious problems of data processing, both for immediate operational use and for any research programs that are carried on subsequently. Therefore, automatic data-processing techniques are being studied to meet research needs and to develop operational techniques.

In addition to the research program, the Laboratory has been deeply involved in an experimental operational use program which, it is hoped, will serve as a forerunner of an operational meteorological satellite system.

The research work of the Laboratory, including the operational meteorological satellite system, will be described in detail in numerous subsequent papers. Therefore, in this very brief presentation, only a few points will be discussed, with emphasis on certain topics which may not be covered in the subsequent papers.

Figure 9–1 is a mosiac prepared from pictures taken by TIROS I extending from the eastern north Pacific Ocean across lower California, Mexico, and the United States, to a point just east of Lake Michigan. These pictures give a view of the type of coverage that is obtained with the TIROS satellites. The mosiac in figure 9–1 is composed of pictures taken by the wide-angle camera. Each picture covers an area of about 700 to 800 miles on a side when the camera is pointing straight down, with a larger area covered as the camera points obliquely at the surface of the earth. In the picture at the far right, for example, the horizon can be seen. The two pictures in the lower right and the picture in the upper left were taken with the narrow-angle camera, which views an area approximately 70 or 80 miles on a side when the camera axis is normal to the surface of the earth.

This gives some idea of the comparative resolution of the two camera systems and what might be classed as normal pictures from both TIROS I and TIROS III. As mentioned in paper 8, the wide-angle pictures in the case of TIROS II were fuzzy and lacked detail.

The high-resolution picture showing Tiburon Island, in the Gulf of California, embraces the outlined area shown in the corresponding wide-angle picture. The distance between the island and the coast is about 1 to 1½ miles; this gives a fair idea of the resolution that can be obtained.

The cloud patterns which exist over the Pacific may be seen in figure 9–1. In general, it has been found that the cloud systems seen by TIROS are highly organized, but this is not always the case. For example, the cloud systems in the pictures on the left are rather chaotic. But even in their chaos they have some organization; note the rolls along the edge of the stratiform cloud. In the last two pictures on the right, clouds associated with a cyclonic vor-

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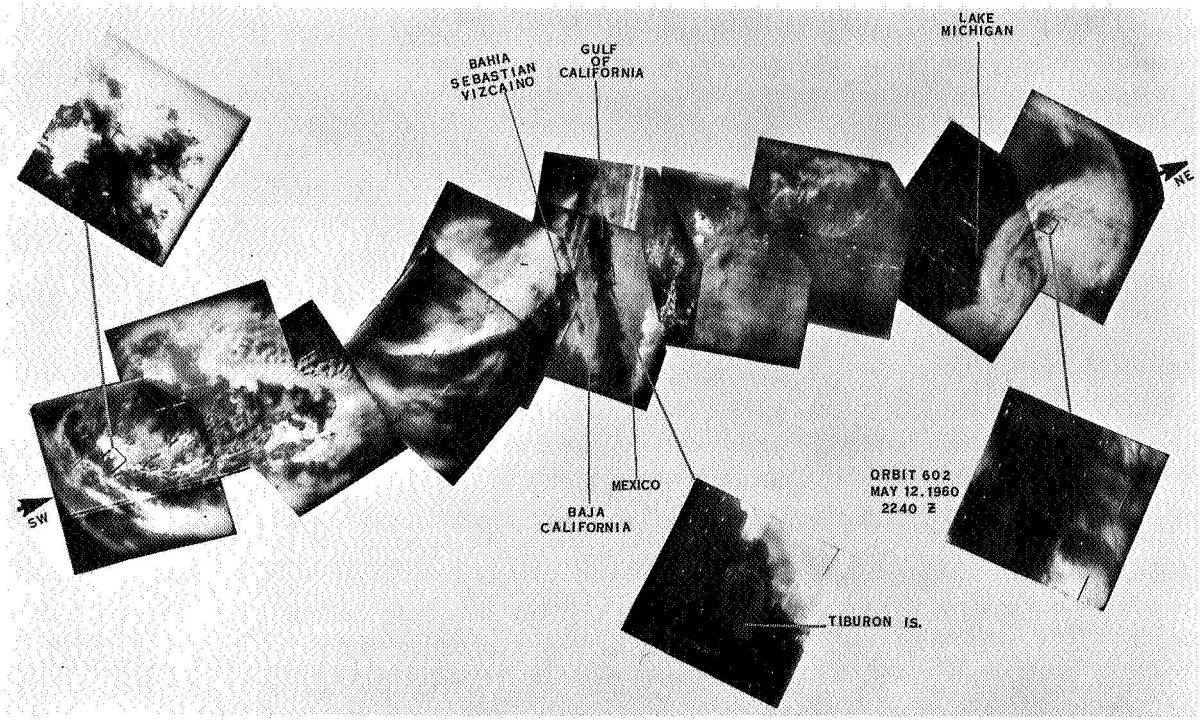

FIGURE 9–1. TIROS I mosaic of clouds over northeastern Pacific to Lake Michigan.

tex located just east of Lake Michigan may be seen.

A bank of stratus over the eastern north Pacific Ocean just off Baja California and the southern California coast is shown in figure 9–2. Generally, stratus exists in the eastern portion of anticyclone patterns and is often found in data-sparse areas; this is a particularly good example. Thus, there is an opportunity, with meteorological satellites, to collect data which can be used for studies of large areas of semipermanent stratus and their associated trade-wind inversion, particularly when radiation data which can be used to infer the temperatures of the tops of the stratus are available on a regular basis.

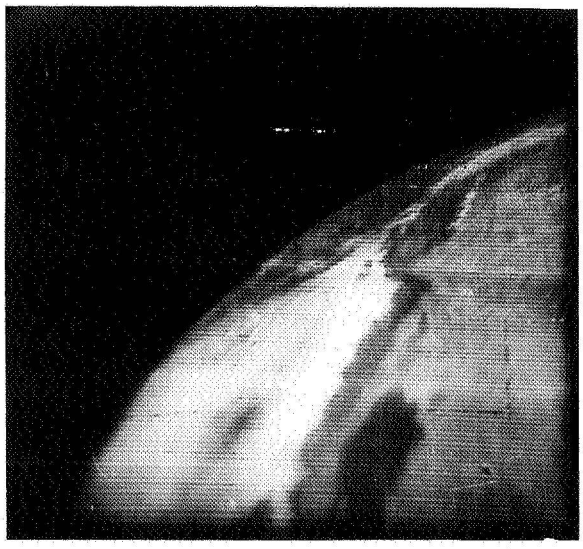

FIGURE 9–2. Stratus off west coast of Baja California.

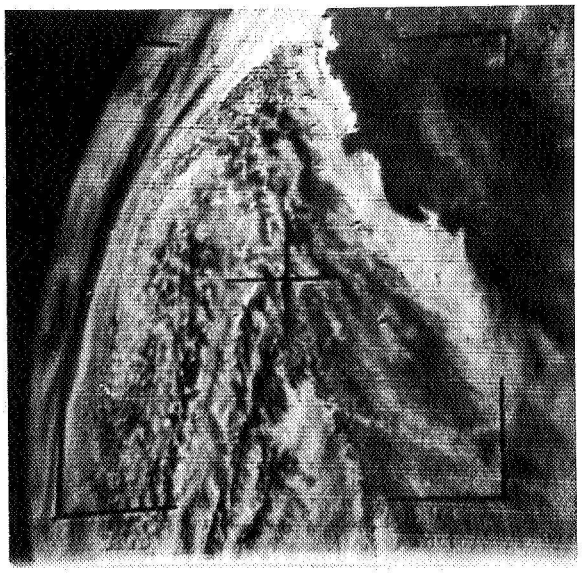

FIGURE 9–3. California coast.

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Figure 9–3 is a photograph of an area including the California coast. Note the darker Y-shaped area which is San Francisco Bay. The water, of course, has the lowest albedo in the picture. Monterey Bay is visible below and to the right of San Francisco Bay. The dark spot just to the right of the center of the vertical portion of the upper right fiducial mark is Lake Tahoe, on the border between California and Nevada. The San Joaquin and Sacramento Valleys and a stratus deck along the coast of California not penetrating inland except at the Golden Gate can also be seen. Note also in this picture a rather weak spiral vortex associated with a dissipating storm system some distance off the California coast over the eastern Pacific Ocean.

TIROS III has been nicknamed by the press as the "Hurricane Hunter" satellite; figure 9–4 shows one picture of a hurricane which resembles to a considerable degree the hurricane symbol which is frequently used by meteorologists. This particular picture shows hurricane Betsy. TIROS III has been particularly notable in its coverage of hurricanes and typhoons, as well as

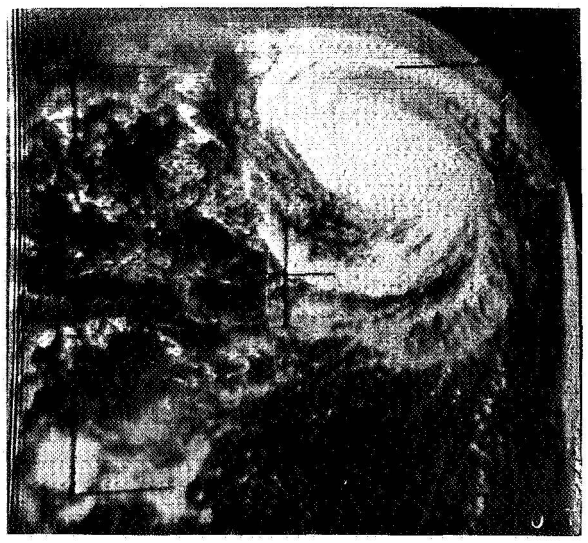

FIGURE 9–4. Hurricane Betsy.

weaker tropical storms and easterly waves. It may be of interest to note the bright cloud mass in the lower left corner of figure 9–4. Although the weather associated with this mass has not been checked by conventional meteorological data, similar masses in a number of other pictures have been noted and the weather associated with them has been reported by conventional means. These bright discrete cloud images appear to be associated with mature cumulonimbus cloud masses and are often indicative of severe local storms. Thus, when this type of image appears in a particular picture, the possibility of a severe local storm should be considered. This connection between severe local storms and hurricanes was particularly notable in the case of hurricane Carla after it moved in over the United States from the Gulf of Mexico.

FIGURE 9–5. Isolated cloud masses over northeast Colorado.

Three cumulonimbus cloud masses over northeastern Colorado as photographed by TIROS I are depicted in figure 9–5. Note that the three isolated cloud images are brighter than the other clouds. Surrounding each of these masses is a relatively clear area, suggestive of rather substantial subsidence. In this particular case the ground observations indicated severe winds, which damaged crops, associated with these three cumulonimbus masses; hailstones as large as 2 centimeters in diameter were observed. More details on this type of phenomenon will be given in subsequent papers.

Figure 9–6 is a picture of mountain wave clouds downwind of the Andes over Argentina; this picture illustrates another particularly useful application for satellite pictures which view such a large area at one time. The Andes can

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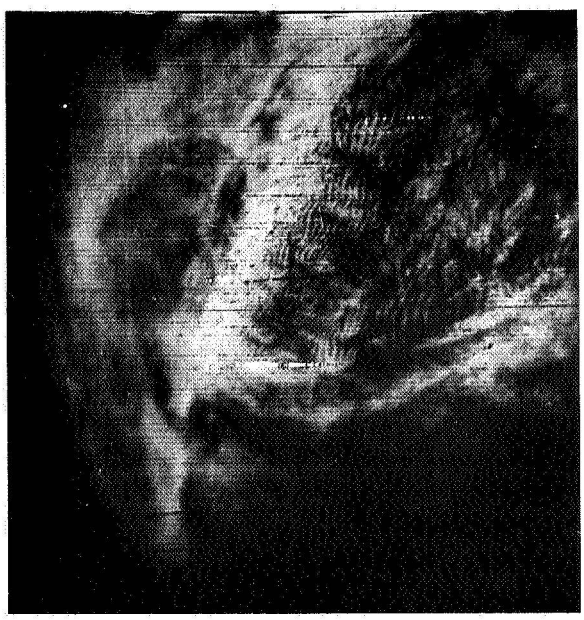

FIGURE 9–6. Mountain wave clouds east of Andes.

be seen just to the left of the center of the picture with the wave patterns extending downwind toward the east. There are two different scales of perturbations visible: the relatively short wavelength, particularly clear near the mountains, and the longer wavelength on which the short wavelength is superimposed. The extent of the wave pattern as indicated by the cloud distribution is of the order of 200 to 300 miles downwind of the mountain ridge.

FIGURE 9–7. Snow cover over Sierra Nevada.

Figure 9–7 illustrates an example of what might be called a borderline meteorological application, the depiction of snow cover. Again, the State of California is pictured with the San Francisco Bay clearly indicated by the specular reflection of the image of the sun. The center of the image of the sun is in the Sacramento River estuary just northeast of San Francisco Bay; the Sierra Nevada mountain range which is mostly snow covered is easily seen. It is oftentimes difficult to discern with certainty in any one picture the difference between snow and clouds. By examining the same area on a series of days, the areas which are definitely snow covered can be differentiated from those which are cloud covered. The cloud system over the eastern Pacific off the west coast of California is associated with an occluded cyclone.

Another fringe application, as far as meteorology is concerned, is ice detection; figure 9–8 illustrates this application. TIROS II was particularly useful in that many narrow-angle pictures were obtained such as these of ice in the Gulf of St. Lawrence area. The figure shows two mosaics of the same area in the Gulf of St. Lawrence extending from west of Anticosti Island to the west coast of Newfoundland. The pictures, taken 6 days apart, make it possible to note the changes in the ice pattern during that period.

Note in the mosaic for March 23, the lead of open water parallel to the northeast coast of Anticosti Island and also the cracks which are beginning to appear in the rather extensive icepack to the east. This area where the cracks appeared and where the ice is darker than elsewhere, which is believed indicative of relatively thin ice, was open water 6 days later, as shown in the mosaic of March 29. The floes range in size from about 1 to 8 kilometers in diameter, and the fields, the solid large areas of ice, are larger than 8 kilometers in diameter.

Some examples of sun glint, which was briefly mentioned in the discussion of figure 9–7, are shown in figure 9–9. The two pictures at the lower right were taken about a minute apart by TIROS I over the Aral Sea. In the left picture of the Aral Sea, the sea, as would normally be expected, is darker than the surround-

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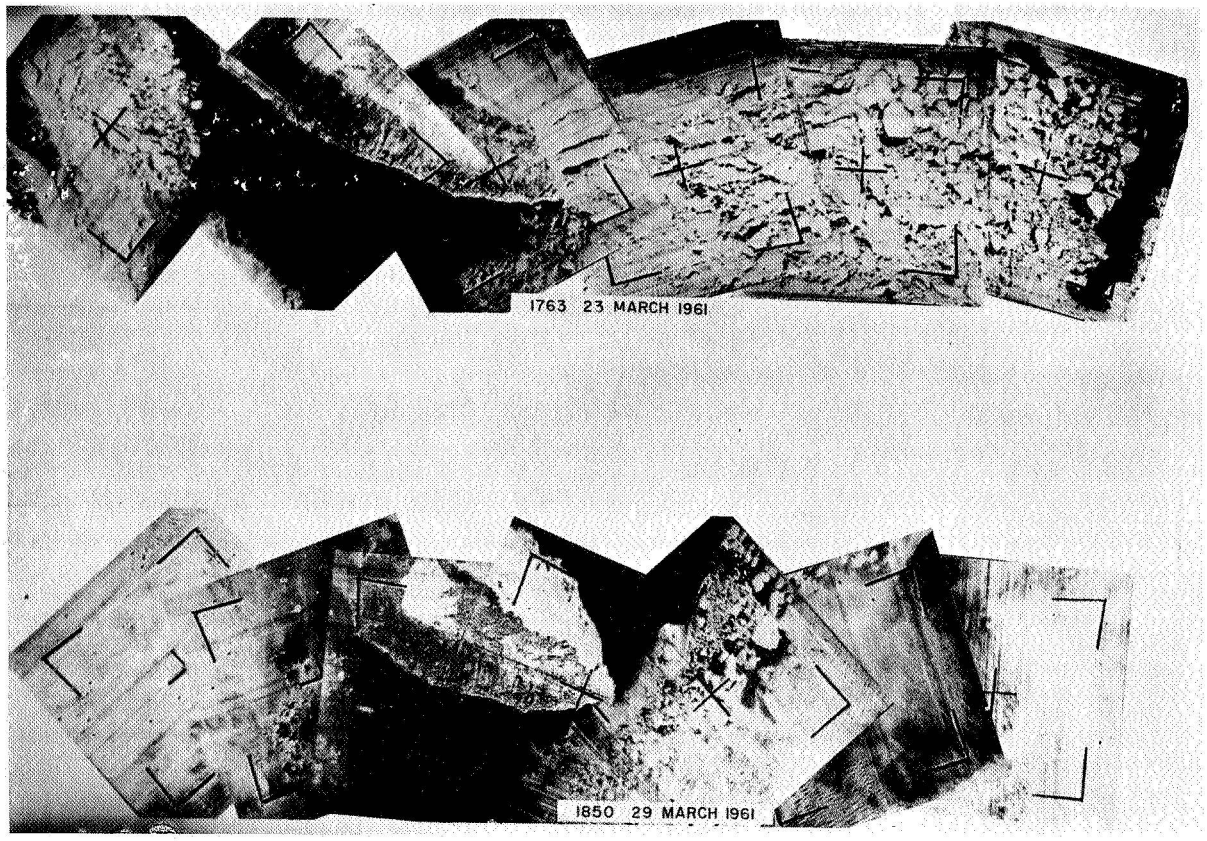

FIGURE 9–8. Mosaics showing ice on the Gulf of St. Lawrence.

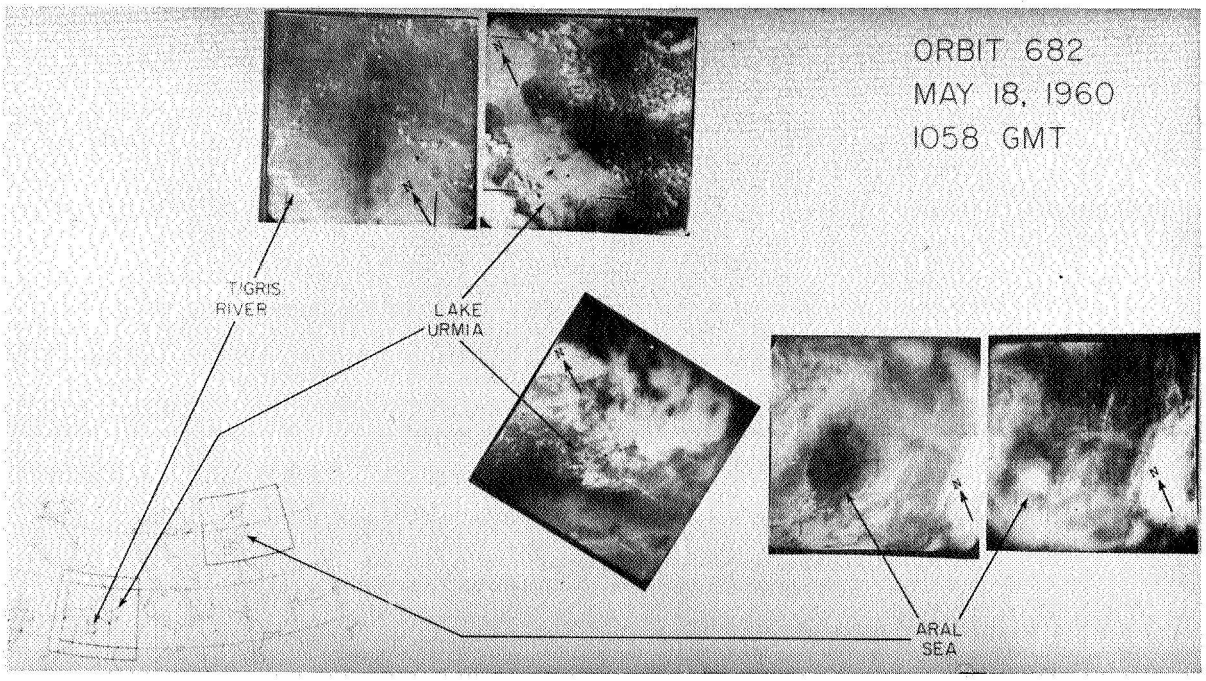

FIGURE 9–9. Sun glint as seen from TIROS.

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ing land or cloud because of its very low albedo. In the picture to the right the image of the sun is reflected by the sea, and the sea is very bright. The conclusion in this particular case, confirmed by supporting observations, is that since the water surface is very smooth, a mirror image of the sun is being seen on the surface. In the upper part of figure 9–9 is a view of Lake Urmia in which the specular reflection is diffuse and rather uniform over the entire lake surface. This leads to the belief that the surface is relatively rough, serving as a diffuse reflector. Thus, there is much interest in the possibility of using the image of the sun, or reflectivity, under clear-sky conditions as an indicator of the ocean surface conditions.

In conclusion, the Meteorological Satellite Laboratory is also active in the interpretation of the radiation measurements which require a great deal more data processing and study before any results can be presented. These results, to date, and some of the problems involved will be discussed in more detail in subsequent papers.